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ORIGINAL ARTICLE

POWER TRAINING IN ELITE YOUNG SOCCER PLAYERS: EFFECTS OF USING LOADS ABOVE OR BELOW THE OPTIMUM POWER ZONE

Running title: Power training in soccer players

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Abstract

This study aimed to examine the effects of two jump squat (JS) training programs involving different loading ranges in under-20 soccer players during a preseason period. Twenty-three elite young soccer players performed sprint speed (at 5-, 10-, and 20-m), change-of-direction (COD) speed, JS peak-power (PP), and countermovement jump (CMJ) tests pre and post four weeks of training. Athletes were pair-matched in two groups according to their optimum power loads (OPL) as follows: lower than OPL (LOPL; athletes who trained at a load 20% lower than the OPL) and higher than OPL (HOPL; athletes who trained at a load 20% higher than the OPL). Magnitude-based inferences were used to compare pre- and post-training measures. Meaningful increases in the PP JS were observed for both groups. Likely and possible improvements were observed in the 5- and 10-m sprint velocity in the LOPL group. Meanwhile, possible and likely improvements were observed in the CMJ, 5- and 10-m sprint velocity, and COD speed in the HOPL group. Overall, both training schemes induced positive changes in athletic performance. Soccer coaches and sport scientists can implement the JS OPL-based training schemes presented here, either separately or combined, to improve the physical performance of youth soccer players.

Keywords: team-sports, football, speed ability, vertical jump, optimal loads.

Introduction

Improving speed and power performance during professional soccer preseasons has long been considered a major challenge for coaches and sport scientists (28, 30, 31). This issue is typically associated with the well-established concurrent training effects, which appear to hamper the adequate development of neuromuscular capacities in periods where high volumes of aerobic exercise (e.g., technical and tactical workouts) are applied (10, 15, 19, 28). For some authors, the interference between endurance, speed, and power adaptations can be explained by several factors such as:1) the inability of muscle to adapt to distinct stimuli due to simultaneous requirements from different metabolic pathways; 2) residual fatigue induced by successive training sessions; 3) age, individual training background, and physiological traits; and 4) the type of resistance training program (33, 39). Among these aspects, the latter is the only one that practitioners can manipulate in certain ways.

More recently, the optimum power load (OPL) has been used as a practical and effective alternative to improve speed and power performance in elite soccer players (24, 26). The "optimum power zone" can be defined as the range of loads able to maximize power output in some resistance exercises (25). This mechanical phenomenon usually occurs at light or moderate loading conditions (i.e., ~30-70% one-repetition maximum [1RM]), and varies according to the lift in question (e.g., bench press or half squat) and its respective mode of execution (e.g., traditional or ballistic) (9, 18, 27). The OPL is typically found at a narrow range of bar-velocities, independent of subjects' training background, sport discipline, and strength-power level (22, 25, 35). Importantly, it has been reported that this load is capable of improving the physical capacities at both ends of the force-velocity curve (i.e., high force, low velocity portion; low force, high velocity portion) and counteracting the speed-power decrements which normally occur in response to congested soccer preseasons (21, 28, 30, 31, 38). However, it is still unknown how the power-load relationship is affected when athletes train immediately below or above the optimum training intensity (e.g., using loads 20% higher or lower than the OPL).

In this context, it has been suggested that training with lower loads and higher velocities might lead to greater adaptations in speed qualities, whereas training with higher loads and lower velocities would result in superior gains in strength-related performance (4, 7-9, 17). Accordingly, in a study with soccer players who trained under different loading conditions for 6 weeks (i.e., "reduced velocity group" [RVG] and "increased velocity group" [IVG]), the authors detected higher increases in leg press 1RM in the RVG. In contrast, greater improvements in linear and change of direction (COD) speed were noted for the IVG (23). Similarly, McBride et al. (29) compared the effects of an 8-week training program with heavy- (80% 1RM) versus light-load (30% 1RM) jump squats (JS) on various physical measures, observing an overall trend toward enhanced velocity capabilities (e.g., 10-m sprint time, peak power [PP], and peak velocity at 30% 1RM) in the light-load group. On the other hand, the heavy-load group showed significant improvements in PP and peak force (only) at heavier loading conditions (i.e., 55-80% 1RM) and, remarkably, presented a significant and unexpected decrease in sprint performance over very-short distances (i.e., 5-m) (which also supports the concept of velocity-specificity in strength-power training) (7).

Therefore, it is important to establish an upper (and also a lower) limit of loads capable of eliciting positive changes in both speed and power-related capabilities. This is particularly relevant in elite soccer, where straight sprinting and explosive actions (e.g., vertical jumps) play a crucial role, being directly related to decisive game situations (i.e., scoring or assisting a goal) (12). Considering the aforementioned challenges and the effectiveness of OPL in promoting positive adaptations and reducing the possible impairments in speed-power performance during high-volume soccer preseasons (28), it is reasonable to use this range of loads as a basis for defining the inferior and superior power-training zones. The aim of this study was to examine the effects of two different JS training programs (using loads 20% higher or 20% lower than the OPL) on the athletic performance (e.g., linear speed, COD speed, and loaded and unloaded jumping ability) of elite young soccer players during a preseason period.

Methods

Participants

Twenty-three male under-20 players from the same soccer club with at least six years of experience in a professional academy (age: 18.3 ± 0.7 years, ranging between 18 and 19 years; height: 178.3 ± 5.4 cm; body-mass [BM]: 71.5 ± 6.5 kg) regularly competing in the most important regional Brazilian youth tournament took part in this study. Athletes were pair-matched in two training groups according to the load associated with maximum PP output (i.e., OPL) in the JS exercise as follows: lower than optimum power load (LOPL, n = 12; athletes who trained at a load 20% lower than the OPL) and higher than optimum power load (HOPL, n = 11; athletes who trained at a load 20% higher than the OPL). The study protocol took place during a four-week preseason training phase, after a four-week period without any programmed training sessions. The study was approved by the local Ethics Committee and the participants signed an informed consent form prior to research commencement.

Study design

A parallel two-group, randomized, longitudinal design was conducted to test the effectiveness of two distinct training programs on the neuromuscular performance of elite young soccer players during a four-week preseason training period (Figure 1). Players were grouped in pairs according to the baseline results of their PP output in the JS, and subsequently the group allocation was performed by tossing a coin. All athletes had been previously familiarized with the performance tests, which were performed in the following order: countermovement jump (CMJ), sprinting speed at 5-, 10-, and 20-m, COD speed, and PP JS. The physical tests were performed on the same day, both pre- and post-training. Prior to all testing sessions, a general and specific warm-up routine was performed, involving light running (5-min at a self-selected pace) and submaximal attempts at each testing exercise (e.g., submaximal sprints and vertical jumps).

*****INSERT FIGURE 1 HERE*****

Training program

During the experimental period, all soccer players performed 12 power-oriented training sessions. The players involved in this study participated in all power training sessions during the preseason training period. A typical weekly training schedule is presented in Table 1. The power training sessions consisted of performing 6 sets of 6 repetitions of the JS exercise at a load corresponding to either 20% lower than the OPL (LOPL group) or 20% higher than the OPL (HOPL group). These loading intensities were chosen because at ±20% of the OPL, athletes usually produce ~90% of their maximum power output in the JS exercise, which can still be considered a substantial amount of power. For both groups, the training loads were controlled and adjusted every four training sessions according to the OPL-based values, as follows: (sessions 1 – 4) OPL; (sessions 5 – 8) 1.05 x OPL; (sessions 9 – 12) 1.10 x OPL(28).

*****INSERT TABLE 1 HERE*****

Testing Procedures

Vertical jumping tests

Vertical jump height was determined using the CMJ. The soccer players were instructed to execute a downward movement followed by complete extension of the legs. All attempts were executed with the hands placed on the hips. The CMJ was performed on a contact platform (Elite Jump System®; S2 Sports, São Paulo, Brazil). A total of five attempts were allowed, interspersed by 15-s. The best attempt was retained for data analysis purposes.

Peak power in the jump squat exercise

Maximum PP output in the JS was assessed on a Smith machine (Hammer Strength, Rosemont, IL, USA). Players were instructed to execute two repetitions at maximal velocity for each load, starting at 40% of their BM. Athletes executed knee flexion until the thigh was parallel to the ground (~100° knee angle) and, after a command, jumped as fast as possible without losing contact between their shoulder and the bar. A load of 10% BM was gradually added until a decrease in PP was observed. A 5-minute interval between sets was provided. To determine PP, a linear transducer (T-Force, Dynamic Measurement System; Ergotech Consulting S.L., Murcia, Spain) was attached to the Smith machine bar. The load corresponding to the maximum PP value was considered as the OPL and was used as a reference to calculate the loads for both groups of training. The maximum PP values for the loads corresponding to the OPL, 20% lower than the OPL (-20% OPL), and 20% higher than the OPL (+20% OPL) relative to the players' BM were retained for analysis.

Sprinting speed

Four pairs of photocells (Smart Speed, Fusion Sport, Brisbane, AUS) were positioned at the starting line and at the distances of 5-, 10-, and 20-m. The soccer players sprinted twice, starting from a standing position 0.3-m behind the starting line. The sprint tests were performed on an indoor running track. Sprint velocity (VEL) was calculated as the distance traveled over a measured time interval. A 5-min rest interval was allowed between the two attempts and the fastest time was considered for subsequent analyses.

Zigzag change of direction speed test

The COD course consisted of four 5-m sections marked with cones set at 100° angles, on an indoor court (Figure 2). Athletes were required to decelerate and accelerate as fast as possible without losing body stability. Two maximal attempts were performed with a 5-min rest interval between attempts. Starting from a standing position with the front foot placed 0.3-m behind the first pair of photocells (i.e., starting line), athletes ran and changed direction as quickly as possible, until crossing the second pair of photocells, placed 20-m from the starting line. The fastest time from the two attempts was retained for analyses.

*****INSERT FIGURE 2 HERE*****

Statistical Analysis

Data are presented as mean ± standard deviation (SD). To analyze the differences in the CMJ, VEL in all distances tested, COD velocity, and PP JS in both LOPL and HOPL groups, pre- and post-training, the magnitude-based inferences were calculated

(3). The magnitude of the within-group changes in the different performance variables, or between-group differences in the changes, were expressed as standardized mean differences. The smallest worthwhile change was set by using a small effect size (ES = 0.2) for each variable tested (16). The quantitative chances of finding differences in the variables tested were assessed qualitatively as follows: <1%, almost certainly not; 1% to 5%, very unlikely; 5% to 25%, unlikely; 25% to 75%, possible; 75% to 95%, likely; 95% to 99%, very likely; >99%, almost certain. A meaningful difference was considered using the Clinical inference, based on threshold chances of harm and benefit of 0.5% and 25% (16). Additionally, the magnitudes of the standardized differences were interpreted using the following thresholds: <0.2, 0.2-0.6, 0.6-1.2, 1.2-2.0, 2.0-4.0, and >4.0 for trivial, small, moderate, large, very large, and near perfect, respectively (16). All performance tests used herein demonstrated small errors of measurement, as evidenced by their high levels of accuracy and reproducibility (coefficient of variation <5% and intraclass correlation coefficient >0.90 for all assessments) (16).

Results

Figure 3 shows the comparisons of the PP outputs in the JS exercise for the different loads tested pre and post the preseason training period in both training groups. Likely to very likely increases were observed in the PP comparing pre- and post-training measurements in the LOPL group in the three loads analyzed (ES = 0.64, 0.68, and 0.54, for -20% OPL, OPL, and +20% OPL, respectively). Meanwhile, a possible increase was noted in the PP JS in the HOPL group for the OPL and the +20% OPL (ES = 0.23 and 0.48, respectively).

*****INSERT FIGURE 3 HERE*****

Table 2 shows the comparisons of the CMJ height, and sprint and Zigzag velocities pre and post the preseason training period. A likely and a possible increase in the VEL 5-m and VEL 10-m were detected in the LOPL group, respectively. In the HOPL group, a possible improvement in CMJ height, VEL 5-m, and VEL 10-m was observed, while a likely increase was detected in the COD velocity.

*****INSERT TABLE 2 HERE*****

Figure 4 shows the standardized mean differences (ES) for the comparisons of the between-group delta changes in the physical tests performed. No meaningful differences were observed for the CMJ, VEL 5-, 10-, and 20-m, and Zigzag (ES [% chance] = 0.15 [36/63/01], 0.09 [29/30/41], 0.05 [27/38/35], 0.13 [40/47/13], and 0.42 [70/23/7], respectively). In addition, the LOPL group demonstrated higher increases in the PP JS for the -20% OPL and OPL (ES [% chance] = 0.51 [02/15/83]and 0.59 [01/11/88], respectively) in relation to the HOPL, while no meaningful differences were noted in the PP JS for the +20% OPL (ES [% chance] = 0.14 [26/29/45]).

*****INSERT FIGURE 4 HERE*****

Discussion

The study compared the effects of two different JS training programs (using loads 20% higher or 20% lower than the OPL) in elite young soccer players during a preseason period. The main findings were: 1) despite the use of lower loads, the LOPL increased power production over the entire range of loads (-20% OPL, OPL, and +20% OPL); 2) the HOPL improved power output only at higher loading conditions (OPL, and +20% OPL); and 3) overall, both training schemes were able to induce positive changes in athletic performance, with meaningful and relevant differences between them.

Despite some controversy regarding this issue, several studies have demonstrated that neuromechanical adaptations are velocity-specific (4, 7-9, 17). For example, Brown and Whitehurst (5) compared the effects of “fast” (4.18 rad·s^{-1}) and “slow” (1.04 rad·s^{-1}) isokinetic training on force and “rate of velocity development”, showing that significant improvements in acceleration occur exclusively at the trained velocity, which, according to the authors, might serve to counterbalance force deficits in power production (when considering the force-velocity relationship). Similarly, a study of under-20 soccer players indicated that increasing bar-velocity during JS (using a system composed of elastic bands) favors adaptations at the high-velocity, low-force end of the force-velocity curve. In contrast, decreasing bar-velocity (by adding traditional weights to the barbell) during JS favors adaptations at the low-velocity, high-force end of the curve (23). Interestingly, in the current study, both training strategies were capable of enhancing power output at distinct force-velocity zones (Figure 3), which could be a direct consequence of training with load intensities near to the OPL (i.e., ±20% OPL). Nonetheless, the light-load group (LOPL) improved power production at all assessed zones (including at the heavier zone), whereas the heavy-load group (HOPL) increased power output only at the OPL and +20% OPL. As previously suggested, it is likely that lighter loading conditions elicit greater gains in power-related capabilities, especially when these loads are utilized in ballistic exercises (e.g., JS) (7, 9, 32). Although the mechanisms behind this apparent superiority are unclear, it could be speculated that the higher movement velocities achieved with lighter loads may increase the rate of neural activation (by changing the pattern of motoneuron firing frequency) and provoke greater adaptations in the inter-muscular coordination by, among other things, reducing the coactivation of the antagonist muscles (6, 7). These factors possibly impact the power production not only at the high-velocity zones, but across different ends of the force-velocity curve, including at the low-velocity, high-force portion. This appears to be an extra advantage in elite soccer, since light-load training probably produces lower levels of fatigue than heavy-load training, allowing players to effectively execute their technical and tactical practices (1, 14, 34).

Improvements in sprinting and jumping performance are usually small (or even nonexistent) during soccer preseasons (21, 28, 30, 31, 38). Loturco et al. (28) analyzed the effects of JS or half-squat executed at the OPL throughout a 4-week preseason phase and noted that both exercises were only capable of "counteracting" the speed and power decrements in professional soccer players. Likewise, Meckel et al.(30) observed that both continuous and interval training methods induced significant increases in aerobic fitness in young soccer players after a short-term preseason, however, these approaches also lead to stagnation or deterioration in anaerobic performance (e.g., vertical jumps). These chronic responses seem to be commonplace in various team-sport disciplines, which, as previously mentioned, may suffer negative consequences due to the interference phenomenon between concurrent aerobic and strength-power training (10, 15, 19). Importantly, these adverse effects can also hamper the adequate evolution and maintenance of strength, power, and speed capacities across the competitive (in-season) periods (11, 37, 38), which may compromise athlete performance and increase the risk of injury during matches (20, 40). As a consequence, the development of novel and more suitable resistance training schemes is a current and critical issue in soccer. Besides its easy implementation (the OPL can be determined by rapidly assessing bar-velocity or jump height (25)) and apparent effectiveness (24, 26, 28), the opportunity to use the OPL as a basis for defining lighter or heavier loading intensities emerges as a new strategy to enhance the functional performance of elite soccer players in different training phases (or according to the athletes' needs). For example, our data showed that HOPL was superior for increasing COD speed and CMJ height, whereas LOPL was more efficient for improving very-short sprint performance (i.e., VEL 5-m) (Table 2). To some extent, these results are in accordance with previous studies that found meaningful improvements in COD speed in team-sport players who trained at (or close to) the OPL (13, 23, 24, 26) and greater increases in speed (e.g., 5- and 10-m) in those who executed JS at higher velocities (when compared to a "decreased velocity group") (23). Nevertheless, all these investigations were carried out over short periods of time (i.e., ≤6 weeks), making it difficult to determine the long-term effects of training under optimum loading conditions. This should certainly be addressed in future studies with longer follow-up periods.

Finally, it is important to note that we employed a restricted number of functional tests including COD, linear speed, and jump tests, which is a common and consistent practice in studies involving elite soccer players (23, 24, 26). However, soccer-specific tasks (e.g., kicking, jumping to contest ball possession, tackling, etc.) may benefit from increases in the power output at distinct zones of the force-velocity curve. These technical and physical capabilities were not assessed in this research. It is probable that the OPL-based methods used here (especially the LOPL) may positively influence these critical game actions, supporting their utilization as a novel and promising training strategy for soccer athletes. This research is limited by its short duration (i.e., 4 weeks) and the use of a single exercise (i.e., JS) in the experimental design. In contrast, the intervention was conducted throughout an actual soccer preseason, with players competing in the most important regional Brazilian youth tournament, which reinforces its applicability and ecological validity. We also recognize that (with the exception of the PP values and VEL5-m) the majority of physical improvements detected here were "small" (ES varying from 0.23 to 0.41), which is a regular occurrence in preseason conditioning programs (28, 30). Further studies using different exercises and more varied training approaches (e.g., combining both HOPL and LOPL regimes) are required to confirm and extend our findings. Moreover, it is recommended that the effectiveness of these training strategies be verified over long-term interventions, especially during the competitive phase of the soccer season.

Conclusion

This work has important practical implications which can be summarized as follows: 1) the OPL is possibly the heaviest loading intensity able to enhance power production under light and very-light load conditions in soccer players during congested training periods. This is reinforced by a previous study which compared the effects of OPL versus traditional strength-power periodization (24); 2) JS training at higher loads (e.g., OPL +20%) may be necessary for improving COD performance in team-sport athletes. This conclusion is based on the current data and preliminary investigations demonstrating the importance of vertical force production in COD performance (36); and 3) loading ranges “immediately” below the OPL (i.e., OPL -20%) appear to be effective for increasing very-short sprint ability (i.e., 5-m) in soccer players, even during short preseasons. A probable explanation for this effectiveness is related to the lower levels of fatigue generated by light loads (14), which is certainly a great advantage in elite soccer settings (especially when considering the critical role of maximum acceleration and speed in modern soccer) (2, 12). Soccer coaches and sport scientists can implement the JS OPL-based training schemes presented here, either separately or combined, according to individual necessities and specific playing tasks.

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FIGURE CAPTIONS

Figure 1. Schematic presentation of the study design. CMJ: countermovement jump; VEL: sprint velocity; PP: peak power; JS: jump squat exercise; OPL: optimum power load; LOPL: lower than OPL group; HOPL: higher than OPL group.

Figure 2. Schematic presentation of the Zigzag change of direction speed test. The circles represent the positions of the photocells.

Figure 3. Comparisons of the relative peak power (PP) in the jump squat exercise pre and post the preseason training period in both training groups. The loads corresponding to the optimum power load (OPL), 20% lower than the OPL (-20% OPL), and 20% higher than the OPL (+20% OPL) were analyzed. LOPL: lower than OPL group; HOPL: higher than OPL group; $^{+}$possible, $^{\#}$likely, and *very likely within-group effect of time.

Figure 4. Standardized mean differences for the comparisons of the between-group delta changes in the countermovement jump (CMJ) height, sprint velocities (VEL) in 5-, 10-, and 20-m, Zigzag change of direction velocity, and the relative peak power in the jump squat exercise using loads corresponding to the optimum power load (OPL), 20% lower than the OPL (-20% OPL), and 20% higher than the OPL (+20% OPL). LOPL: lower than OPL group; HOPL: higher than OPL group; the grey area represents the smallest worthwhile difference which corresponds to a small effect size (0.2); error bars represent the 90% confidence limits; $^{\#}$likely difference in relation to HOPL group.